DOCUMENT RESUME

ED 383 569 SE 056 523

AUTHOR Feldman, Allan
TITLE A Tale of Two "isms": Constructivism in Practice.
PUB DATE Apr 95
NOTE 38p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (San Francisco, CA, April 22-25, 1995).
PUB TYPE Viewpoints (Opinion/Position Papers, Essays, etc.) (120)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Biographies; *Case Studies; *Constructivism (Learning); *Definitions; Educational Theories; Elementary Secondary Education; *Epistemology; *Science Instruction

ABSTRACT

The opinion in this paper is that there is a need to reexamine the meaning of constructivism in an age where the concept has come to mean different things to different people. This paper examines one person's understanding of constructivism in order to uncover multiple meanings of the term in ways that ultimately affect teachers' practice in K-12 education. The case study and its associated analysis is a combination of a case study that is biographical and a critical analysis of what is meant by constructivism, using personal perspectives and guided by the insight gained through the case study. Data for the case study came from the published and unpublished writings of the subject and interviews conducted with the subject. The critical analysis is in part a hermeneutic review of the literature. The paper concludes by linking various meanings of constructivism to three problematic areas: confusion over what is meant by knowledge, identification of who learners are, and the application of constructivist theories in classroom practice. (LZ)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 383 569

A Tale of Two "isms": Constructivism in Practice

by

Allan Feldman

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Allan Feldman

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

SE056523

BEST COPY AVAILABLE

A tale of two "isms": Constructivism in practice

Allan Feldman
University of Massachusetts at Amherst

At this time, near the end of the 20th century, it can be said, with only slight exaggeration, that we are all constructivists (Matthews, 1992). References to constructivism are found in the language of national and state reform efforts, curriculum development efforts, new forms of assessment, and the philosophy statements of universities, colleges, and schools. But when an "ism" is accepted by a wide variety of people and institutions, as is the case with constructivism, it loses meaning as it becomes different things to different people in different situations (Good, Wandersee, and St. Julien, 1993).

What I would like to suggest is that there is a need to stop to think about what constructivism has come to mean. I do that in this paper by examining one person's understanding of constructivism. In doing so, I hope to uncover the multiple meanings of the term -- meanings that are consonant and dissonant, or at most loosely linked, with one another. While this may at first seem ambitious given the sample size, truly an "n of 1," I feel that this is possible because of some of the aspects of this singular case. I also feel that this is possible because my goal here is not to look at this single case and to generalize to others, but rather to allow me, and the readers of this paper, to come to a better understanding of what is meant by constructivism through examining its meaning in this illuminating case -- that of a high school science teacher who adheres to two "isms" -- constructivism and fundamentalism.[1]

Before I recount the particulars of this case, I want to make explicit the method that I have used. This case study and its associated analysis is a combination of two forms of scholarly endeavor. The first is a form of case study that is biographical: This is a case of a single person whose personal history and current situation have played a

A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA, April 22-25, 1995.

ED385523

major part in the development of his conceptions of science, science teaching, and constructivism. The second is a critical analysis of what is meant by constructivism, using the perspectives of other authors and guided by the insight gained through the case study. It is important for me to make clear that this is not a linear process -- just as the case study influenced the critique, new understandings that I have gained from the critical analysis have influenced the case study. The circularity here is both intentional and unavoidable; just as is the thought that this process is itself constructivist in nature.

Data for the case study came primarily form two sources: the published and unpublished writing of the subject[2], and my interviews with him. Additional data comes from a research journal that I kept that included notes of my numerous conversations with him over the two years that we were both a part of the same state-wide reform effort in science education. The case study was written using the methods described by Yin (1989), as well as Goodson's methods for constructing teachers' biographies (1991). In addition, I relied on Miles and Huberman's (1984) methods of analyzing qualitative data.

The critical analysis is, in part, a hermeneutic review of the literature in which I look at the ways that various authors have made use of language. In this way it is similar to literary criticism. However, my point here is not just to uncover textual meanings but to do so in ways that ultimately affect teachers' practice in K-12 education.

I begin the paper with a biographical sketch that describes an individual's development as a science teacher and as a Evangelical Christian. I follow this with my construction of his epistemology and his ways of thinking about constructivism in science education. I then relate his use of constructivism as a modifier to the way it is use by various authors in the literature. I conclude the paper by linking these various meanings of constructivism to three problematic areas: confusion over what is meant by knowledge, identification of who learners are, and the application of constructivist theories in classroom practice.

Constructivism in practice

The subject of this case is Mr. Pilgrim, a high school science teacher who adheres to two "isms": constructivism and fundamentalism. His background in science is primarily in physics, with a BA in the discipline from a campus of the California State University (CSU) system. During his undergraduate years he also became involved in Evangelical Christianity through Campus Crusade for Christ and the Calvary Chapel of Costa Mesa. There should be no surprise that someone can be both a science teacher and a fundamentalist --the various forms of "creation science" are models for doing so. But there does seem to be some dissonance between constructivism and fundamentalism, especially if one thinks of constructivism as a rejection of the positivism that is epitomized by strict interpretation of the bible.

Mr. Pilgrim underplays this contradiction for reasons that I will explore later in this paper. But first I want to present two examples of his adherence to constructivism: the first in a secular setting, and the second in his role as a teacher of adult Bible studies.[3]

A constructivist lesson workshop

As part of his involvement in a state-wide reform effort in science education, Mr. Pilgrim developed and presented an inservice workshop to help other teachers learn how to prepare constructivist lessons.[4] The workshop followed a specific five-step outline that Mr. Pilgrim sees as a template for constructivist lessons: Orientation, Elicitation of Student Ideas, Restructuring of Ideas, Application of Ideas, and Review of Change in Student Ideas (Pilgrim, undated).

The workshop followed the same format: First he began with an orientation and elicitation of ideas about lesson planning by having the participants prepare group posters on the steps of a "generic" laboratory activity. He then began a "restructuring" of the participants ideas with a presentation of the sequence for a constructivist lesson

plan. The participants then "applied and evaluated their newly reconstructed ideas about lesson planning" by doing a laboratory activity on light and color. Finally, Mr. Pilgrim led a discussion of participants' responses to a questionnaire on constructivism. While Mr. Pilgrim was not pleased with how the workshop went when he presented it (OP, C 8091)[5], his model for a constructivist lesson matches the structure found in the literature of constructivism (Brooks and Brooks, 1993; Leonard, Gerace, and Dufrense, 1994).

Bible study class

Mr. Pilgrim's interest in constructivism also touched his church activities. He is an ordained pastor and has been teaching adult Bible study classes for many years. But once he was exposed to the ideas of constructivism, he felt that he "could never return to the direct method of teaching again (OP, C 8517)." He then began to apply his conception of constructivism to his "ministry as a Bible teacher (OP, C 8517)." He wrote about it in this way:

> In addition to my use of constructivism in my science classes, I conducted a seven week (ten and a half hour) Bible study classes for my Calvary Chapel church using the constructivist approach. Questionnaires and group discussions were used along with lectures (Bible exposition) in the restructuring and application stages. The adults who participated enjoyed making posters and giving feedback to the class during the elicitation and review stages. All were surprised and excited about the change in their beliefs, ideas, and attitudes. Most of these over fo ty years of age participants remarked that learning had not been this much fun since grade school (OP, C 7686).

Mr. Pilgrim used his constructivist ideas about teaching with his Bible study classes because he was excited about constructivism and convinced of its effectiveness

(Personal communication, 1994). He felt that it was more than just talking at people -- like giving a sermon -- and could help to bring about change in people's lives.

And so he used his constructivist pedagogical methods, providing experiences for the adults in his Bible study classes including community experiences, the writing of plays and essays, making posters, brainstorming, by filling out attitude surveys, or by having them explain what they were thinking while reading newspaper articles. For example,

> a typical one was the story of Jesus and the Good Samaritan. ... they had to rewrite that story within a contemporary "punk rock" context in the form of a mystical play. And people said, "You mean I'm going to rewrite the Bible?" I said "In a sense. You're going to take that story and rewrite it, recontextualize it for this value, for today." A few thought that was sacrilegious at first. After they did it they said "Now I understand what that story is saying ." ... And it's not from me, the preacher, explaining that to them, but they experienced it (IN, C 11885).

From these two vignettes, it appears that Mr. Pilgrim sees little conflict between constructivism and fundamentalism. Unfortunately, this was not the case for the pastors of his church, who refused to allow him to continue to teach the Bible study classes.

Biography

In this section of the paper, I present the case in the form of a teacher's biography. It focuses primarily on two aspects of Mr. Pilgrim's life: how he became a science teacher and his acceptance of Christian fundamentalism. I begin with his schooling.

Schooling

Mr. Pilgrim, a man in his mid-forties, has lived most of his life in Southern California. He attended school near Los Angeles, where from kindergarten through 10th

grade, he was placed in special education classes, including speech therapy and adaptive physical education. But then

> during summer break after tenth grade, I experienced many epileptic seizures requiring hospitalization. After that, I slowly improved academically through the next two years. In my senior year of high school, I successfully completed physics, calculus, and Latin. Just prior to graduation, I was awarded the Bank of America Award for Math and Science, the Director's Award for Music, and a full four-year state grant for the educationally handicapped (OP, C 2459).

After graduating from high school, Mr. Pilgrim attended a local community college for two years. It was during these years that he changed his major from engineering to physics. He then attended a campus of the California State University (CSU) where he majored in physics and in 1972 he completed his BA to become the only person on both sides of his family to complete a college degree.

In retrospect, he wishes that he had majored in sociology, because "sociology, theology and international relations are all subjects that really interest me now (IN, C 9879)." These interests had their origins in other college experiences that led him to spend four years traveling on the road through most the United States drumming in a "Jesus band" before becoming a teacher.

Becoming a Christian

It was during his junior year of college that Mr. Pilgrim became involved with Campus Crusade for Christ and "became a Christian." Mr. Pilgrim described Campus Crusade as "engineered discipleship ... a very good way of getting people to gain quickly a lot of knowledge and experience, and usually, understanding and wisdom as well (IN, C 11697)." In Campus Crusade, people are organized into action groups of 10 or 12 with a leader who leads discussions through "Ten Steps" towards "Christian Maturity." Within two years Mr. Pilgrim had finished the series, and found that "he had

grown in many ways, not just spiritual (IN, C 11697)." He found that "his self-confidence and social skills finally emerged from his awkward, shy self (Personal communication, 1994)."

At the same time he was attracted to another Christian movement which started in the late 1960s -- the non-engineered, charismatic style of the Calvary Chapel in Costa Mesa, CA. This was the "long-haired hippie Jesus movement" that Mr. Pilgrim found attractive because he was a "long-haired rock-and-roller (IN, C 11697)." He has found this to be a "loving kind of place" that he has been committed to for 22 years. His wedding ring with its image of the Holy Spirit dove in the style of the Calvary Chapel is a symbol of his commitment to God and that church (Personal communication, 1994).

Mr. Pilgrim spent four years after college on the staff of Campus Crusade as a "Jesus freak," drumming in a band that played "Christian music" in the style of "Creedence Clearwater Revival, ... Poco, [and] Loggins and Messina." But then he broke his arm, nerves had been severed, he was told that he would never play drums again, and he left the Campus Crusade staff and the band. To the surprise of his doctors, even though he was not able to move his fingers for a year and a half, he was able to drum again within two years of the accident. He often thinks of how things might have been different if he had not broken his arm:

> ... many times I wish I could have stayed in Nashville. But I didn't know my arm was going to recover. The doctors told me my arm wouldn't even grow anymore -- It would be a shriveled stump. That's when I quit. ... But as far as I was concerned, my drumming career was over (IN, C 7831).

It was at that time that he decided to seek his teaching credential.

> I thought if I can't be a professional drummer I'm going to go into teaching because I had been successful working with kids. ... I put myself through college

directing drum and bugle corps, and I had a lot of success, winning several state championships (IN, C 9879).

Mr. Pilgrim got his teaching credential through a preservice teacher education program at a Christian college in the Los Angeles area. He went there instead of a CSU so that he could arrange his course of study so that he could complete the credential program in one year. During that year he held several part-time jobs. He taught music and percussion at the college and was able to work as a youth pastor at a local church. He felt as if all of his interests were coming together at once -- drumming, teaching, and Christianity. And he was exposed to two areas of study that have continued to be of interest to him -- psychology and sociology. He told me that his interest was aroused in these areas because they helped him to understand what had intrigued him, "a southern California city white boy," about the diverse peoples he had met while touring in the band.

Teaching

During the two years that I knew Mr. Pilgrim he taught science at Mountain High School. It is the only high school in a rural district that extends across 110 square miles of mountainous terrain. Mountain High School has an enrollment of approximately 1400 students in grades nine through twelve. Racially and ethnically it is fairly homogenous -- only about 10% of the students could be labeled "minority." The school district includes a well-known and attractive winter and summer resort area, and is within an hour's drive of one of the most rapidly growing regions of California. As a result, there are wide socio-economic differences among the students.

In 1989 Mountain High School (MHS) became involved in a state-wide reform effort in science education, the California Scope, Sequence and Coordination project (CA SS&C).[6] Several of the MHS teachers attended workshops about SS&C and the science department wrote a proposal to be involved in the project. As a result, MHS became one of the "100 schools" to be initially involved in the CA SS&C project.

In this project, teachers in individual schools design instructional materials and pedagogy to move away from the "layer cake model" -- the traditional US approach to science education in which students study biology, chemistry, and physics for a year each in order -- to a more integrated and coordinated model in which all science is taught to all students each year. The science teachers at MHS decided that they would begin to work towards this model by revising the earth science and life science classes that were offered as part of the non-college bound track. A curriculum was written for four semester-long courses that incorporated the earth sciences, biology, chemistry, and physics and was "sequenced according to the six themes in the California Framework (OP, C 2083)."

As was to be the case at other schools involved in the CA SS&C project (Feldman, Mason, and Goldberg, 1992; 1993), the teachers at Mountain High School found that it was quite difficult to implement their new curriculum. As a result, the curriculum was abandoned, and the school decided to adopt FAST (Foundational Approach to Science Teaching), a multi-year middle school science curriculum developed at the University of Hawaii. Mr. Pilgrim describes it as a

> very structured, three year, integrated course utilizing the constructivist approach to the curriculum design of its individual units. The courses also utilize 70% hands-on time, and performance-based assessment (OP, C 2083).

As is required for new teachers of the FAST program, Mr. Pilgrim attended an 80-hour training session on how to implement the curriculum. During the 1992-93 academic year, he taught 5 class sections of FAST 2: The Flow of Matter and Energy through the Biosphere that he titled "Integrated Laboratory Science I."

Mr. Pilgrim's involvement with the CA SS&C project was coincidental with his completion of a master's degree in curriculum design and development. Before this, he had what he calls a didactic teaching style in which he used laboratory activities as a

way to verify what he told his students was true. And although he felt that that was not the best way to teach, he "had absolutely no idea how to do it differently (IN, C 8591)." He describes his current style of teaching as "holistic, integrated, thematic and hands-on (IN, C 12716)." When asked to explain what he meant, he replied, "I try to get students to come up with their own answers as much as I can, and try to prod them along a little bit (IN, C 12716)." Mr. Pilgrim attributes the change to his involvement in SS&C and his work on his master's degree in curriculum design. As a result, "I am no longer the same person ... not just in the way I look at science teaching but in the way I look at my life (IN, C 12716)."

Further education

The pursuance of a master's degree in curriculum design and development can be an ordinary event for many teachers. Many teachers do so to become a better teacher, and continuing professional education is encouraged both through certification and re-certification regulations, and through the tying of pay-scales to the highest degree held. Few teachers, however, seek the master's degree as a result of a vision:

> I had a vision and I don't have epiphanies very often. I've only had one vision in my life, and that vision was what my life goal is. ... The vision was from the inside of a fly's eye -- hundreds of cells of people helping people. And each cell was something different. And I wasn't in any of them (IN, C 11139).

As Mr. Pilgrim reflected on this vision, and his not being in any of the cells -- not being the person in the cell who helps other people -- he began to understand that his goal was to be a helper of helpers.

> And whether it's agriculture or health care or evangelism or discipleship or social justice or relief -- like giving food to victims of hurricanes or war, or battling Apartheid, or protecting trees and unborn children, or providing job training for

> unwed mothers -- whatever I do, my goal, my purpose in life, is to help the helpers. To help the helpers. (IN, C 11139).

Mr. Pilgrim sees himself as someone who can help those who help others, and as a way to respond to the "mandate in Genesis 12:1-3 (Personal communication, 1994)."[7] He feels that the vision through the fly's eye provided him with not only clear sight as to what he should do with his life but also with the skills needed to do it: "With that vision I was given very little knowledge of specific details, but more of understanding and wisdom of how you piece that all together (IN, C 11139)."

A few months after this epiphany, Mr. Pilgrim became involved with a college that trains missionaries and "Peace Corps-type" people, focusing on international health care, community development, and international relations. He enrolled in a course that provided him with a "'Gestaltic' view of theology and missions (Personal communication, 1994)". He began to manage the research library for the division of international development. Then several of the professors began to ask him to design the curriculum for their lessons because while "they were subject matter experts ... they didn't know how to teach (IN, C 11139)." He found himself actually teaching some of their lessons in their classes even though he was "barely familiar with the subject matter (Personal communication, 1994)."

And so even though he had had no training and had had no field experience overseas, he felt that the professors realized that he had an understanding -- "a 'gestalt' that usually takes a decade to develop (Personal communication, 1994)" -- of international development. It was this "God-given" understanding that reinforced Mr. Pilgrim's commitment to his goal to help helpers. He began to envision what this life would be like:

> I would be a sub-contractor working with World Vision or Campus Crusade, people I worked with before, or Green Peace -- I would love that -- different

> missionary organizations. The Peace Corps has expressed interest in me as a director of education for them, not a volunteer, in which I would be supervising the people who give instruction in nursing, agriculture and community development [with] appropriate technology. If I do that, it wouldn't be in say a Christian realm, but it would be helping helpers. And what I'm called to do is help helpers regardless whether it's in a secular or a Christian realm. God hasn't told me that there's an important difference ... (IN, C 11139).

It is this goal that led him to pursue a masters degree in curriculum development.

At the completion of his master's degree program at a CSU campus, Mr. Pilgrim felt that he had experienced a "quantum leap" in his understanding and application of learning theory. Interestingly, he claims that he never came across constructivism in these classes. But through his exposure to the CA SS&C project, attendance at meetings of the California Science Teachers Association (CSTA) and of the National Science Teachers Association (NSTA) he became aware of the constructivist movement in science education. This led him to read some literature on constructivism and to try out ideas in his science classroom, his Bible study classes, and to prepare an inservice workshop to teach other teachers about constructivist lesson planning.

Constructivism

In this next section of the paper, I uncover what Mr. Pilgrim means when he uses the term constructivism. I begin by looking at his conception of knowledge and how he relates knowledge to science.

Truth and reality

Mr. Pilgrim's way of thinking about knowledge and knowing science was evident in my interviews of him, our numerous conversations, and in his writing. He believes that "the physical universe is built upon absolute, objective truth ... some of which is revealed in the Bible(OP, C 8517)" and that "the truth is true regardless of our

experiences ... (OP, C8517)" He wants students to be aware that there is an objective truth and that human endeavors discover it, rather than create it. Mr. Pilgrim believes that human understanding of the "laws of the universe" changes, and will change, and that what people do create is a "superficial understanding of the truth that shifts with time and experience (OP, C 8517)." But the "laws of nature" do not change.

In keeping with his dual interests in science and theology, Mr. Pilgrim has given two examples of why it can be difficult to recognize truth:

> Isaac Newton showed his scientific peers that white light could be broken into the colors of the rainbow by passing it through a clear glass prism. By passing the rainbow through an inverted prism, he showed them that white light could again be made from the colors. Thus, he simply demonstrated the objective laws of light. His jealous, atheist peers accused him of witchcraft, curious since Isaac was a devote Episcopal Bible scholar and beloved Bible teacher. His demonstration violated their beliefs. Simple experiments by them could have easily overcome their prejudice. Their jealousy prevented them from recognizing the truth (OP, C 8517).

> In the nineteenth century, secular archaeologists scoffed at the Bible since they refused to see any evidence of the Hittite nation mentioned in the Book of Genesis had ever been discovered -- providing ammunition for atheists to discredit both the Jewish and Christian religions. Eventually, secular archaeologists discovered evidence that the Hittites were indeed a very substantial kingdom. Though the objective truth eventually became acknowledged, no apology came from the secular archeologists. Their pride prevented them from admitting their error and the negative effect that error had on millions of people (OP, C 8517).

In both of these examples, it is human failings -- jealousy, pride and suspicion -- that got in the way of perceiving the truth about nature and the truth about history. This suggests that while Mr. Pilgrim believes that our understanding of reality can and does shift with time, that human failings often get in the way of seeing the world clearly.

Mr. Pilgrim distinguishes among what he calls knowledge, understanding, and wisdom. By knowledge he means, "ideas and processes and facts (IN, C2336)." To possess knowledge is to know facts, or "to have a feeling of confidence in processes (IN, C2336)." An understanding results from integrating the ideas, processes and facts through a "gestalt, a wholistic awareness of interrelationships (Personal communication, 1994)". To Mr. Pilgrim, wisdom is the ability to use that understanding, choosing when and when not, and in what context, to apply knowledge and understanding. This can be seen in the chart that he prepared to illustrate this for me (Personal communication, 1994).

---------- Insert Chart I Here ----------

So in a sense, Mr. Pilgrim has a multi-level epistemology, with human knowledge toward the center. It is these facts, ideas, and processes that can be true or false relative to an absolute reality. It is the next level, human understanding, that is a result of integrating knowledge, and is constructed. This constructed understanding shifts with human experience through time. The top-most level of Mr. Pilgrim's epistemology is wisdom. By accumulating knowledge, constructing understanding, and using these, a person can demonstrate wisdom and be called wise. By tying wisdom to human action in this way, Mr. Pilgrim places it in the moral domain, and therefore for him, into the realm of religion and practical theology (see Diagram I, prepared by Mr. Pilgrim (Personal communication, 1994)).

---------- Insert Diagram I Here ----------

Knowing science

Mr. Pilgrim's multi-level epistemology influences the way that he talks about science as a specific domain of human knowledge. When I asked him what it means to know science, he replied

> [Y]ou can have knowledge of scientific facts or processes. You could have an ability of integrating scientific ideas and processes and facts into a scientific understanding to get the big picture , the gestalt, to be wholistic. And then ... you could take your knowledge and understanding and determine when and how to use it. That's wisdom. So you've got knowledge, understanding and wisdom. And all of those things should be somehow dealt with in a science class (IN, C 2336).

To Mr. Pilgrim, knowing science consists of having a command of science on all three levels of his conception of knowledge. A person knowledgeable in science would know facts, ideas, and processes; be able to integrate them into understandings; and be able to use them to act wisely.

He explains that most people see science as being divided and subdivided into a multitude of fields. In the past, to be an expert in science required specialization in one sub-field such as optics or botany. But now a person must be an expert in more than one subfield, and be able to integrate them. In addition, to Mr. Pilgrim, to be an expert in science means to be an expert in scientific methodology. He recognizes that "every field has a slightly different scientific method" and that therefore "There is no one generic scientific method (IN, C 2336)."

Although he recognizes that expertise in science is limited to being knowledgeable in only at most a few subfields of science, he is not comfortable with this. He sees it being at odds with the "real world."

> If you look all around here there's geoscience all over the place. [Let's say that] I have a chance to teach about how this mountain got formed,[8] ... to explain to the kids how this mountain formed I couldn't do it just by simply teaching physics or chemistry or geology independently of each other. This mountain didn't form by one process or one discipline at a time. This mountain formed by the simultaneous integration of them all (IN, C 9655).

Because of the way he thinks about science and knowledge, Mr. Pilgrim thinks that there is no reason for students to study science the way that is taught in most schools: "separate disciplines and labs to verify the teacher's or book's statements (Personal communication, 1994)." When students ask "Why study science?" he feels that in most classrooms the appropriate answer is that it is a requirement for graduation and for college admission. Otherwise there is almost no benefit to it. On the other hand, he loves science and argues that it should be taught in schools if it is a means of learning "basic thinking skills, creative thinking skills, cooperative learning, and research (IN, C 8743)." Mr. Pilgrim believes that the best way to teach these skills in a science class is through an integrated, SS&C approach. He wants to see

> chemistry, physics, biology, and ecology all integrated because that's real life. In real life the disciplines are not separate. That's something that society did over hundreds of years, is that they separate science into distinct disciplines. ... If we want the kids to learn and appreciate science then we need to teach it the way it happens in the real world (IN, C 0655).

And finally, while stressing the importance of teaching process skills such as "creative thinking, cooperative learning, and research (IN, C8743),' he does have content

goals for his classes. He believes that courses need both structure and content goals if they are to work. He chooses his content goals based on what is possible for different grade levels and for individual students. He feels that it is important for him to do that, especially in light of the California Science Framework (CSDOE, 1990) and his commitment to the SS&C reform.

So by paying careful attention to the scope, sequence, and coordination of the science content, and by teaching critical thinking, creative thinking, and cooperative learning, there are benefits "that go beyond science (IN, C 8743)." In this way, Mr. Pilgrim's involvement with the CA SS&C project and his adoption of the FAST program are closely tied to the way that he thinks about science, about teaching science, and his ways of thinking about knowledge, understanding, and wisdom.

Constructivism as a modifier

What does constructivism mean to Mr. Pilgrim? In his writing, my interviews of him, and in our conversations, it became clear that, as with many people, Mr. Pilgrim has a complex conceptualization of constructivism. This is evident in the following example:

> In a constructivist classroom, students hopefully reach a consensus concerning a scientific theory. When new knowledge and contexts are gained, their once viable theories must be revised or discarded. In the constructivist classroom, the student's ability to learn from the environment and experiences is elevated far above the acknowledgment of objective facts which are true or false regardless of the student's environment and experiences (OP, C 8517).

In this example, he uses constructivism in several ways. First, he uses it to describe a type of classroom, one that uses a particular set of pedagogical methods. Second, he uses it to describe a learning process that is dependent upon personal experience, and

the context within which those experiences occur. And third, Mr. Pilgrim uses constructivism to describe a way that scientific theories are accepted through consensus.

These ways of using the term constructivism correspond with three different domains that the term modifies. First, constructivism is used to identify a variety of stances within the domain of epistemology. Second, it is used to describe a form of pedagogy. And third, constructivism is identified within the domain of psychology as a learning theory.

Constructivist epistemology

Much of the literature on constructivism in science education is devoted to a discussion of constructivism as a way of understanding what we mean by knowledge, science, and doing science. Its current usage derives from work in the philosophy and sociology of science by Kuhn (1970), Lakatos (1978), and Feyeraband (1975), among others, and it can be traced back to classical and renaissance authors (von Glaserfeld, 1993).

Statements such as:

> Constructivism deals with questions of knowledge -- what knowledge is and where it comes from. It can therefore be considered an exercise in epistemology (von Glaserfeld, 1993, pp. 23-24).

and "To begin with, constructivism is a theory of knowledge (Bettencourt, 1993, p. 39)" place constructivism within the domain of epistemology. Other authors expand constructivism to include psychological and pedagogical uses, but still refer to it within the domain of epistemology (Driver, 1983; Matthews, 1992; and Tobin and Tippins, 1993). Even Noddings' claim that constructivism is postepistemological (1990) places her argument within the domain of epistemology.

Within this domain of epistemology, the concern of authors seems to be the relationship between what we call science and any reality that may or may not exist

separate from human experience. For example, Bettencourt has described three types of epistemological constructivism: In radical constructivism, "the relationship between knowledge and 'reality' as a criterion of truth has been abandoned and substituted by a criterion of fitness." Hypothetical realism conceives of scientific knowledge as a "hypothesis about the structure of reality" that grows closer to but never becomes "perfect knowledge of that reality." And in pragmatic constructivism[9] "knowledge is considered as a constructed picture of the reality of things-in-themselves (1993, p. 44)."

It appears that Mr. Pilgrim is no radical constructivist (von Glaserfeld, 1993). Rather, he "fears that constructivism misapplied will lead learners to learn just for the sake of learning while scoffing at the notion of absolute reality in the physical universe and history (OP, C 8517)." His concern is that by focusing on the learning as construction, students will perceive both the physical universe and history as creations of the human mind rather than as separate realities. This is in-line with his multi-level epistemology and his statements about the nature of truth and objective reality, which suggest that he views scientific knowledge in a way that could be labeled hypothetical realism.

But a look at the way that Mr. Pilgrim relates the historical development of scientific ideas to the teaching of those ideas raises questions about labeling him in that way:

> ... in history we understood compounds before we understood elements. So [we] have the kids smelt compounds, take a look at the physical properties of those smelted [compounds]... try to find out what they can about that. And then begin working with the compounds before they were smelted, doing the same kinds of things with them. ... And based upon these comparisons they're going to get to where they're balancing equations. And then we eventually get to the periodic table. But the way that they get to the periodic table is the way the original

> scientists did by looking at the characteristics of the elements and trying to come up with their own periodic table (IN, C 11435).

In that interview I asked Mr. Pilgrim whether it was important for the students' periodic table to match the periodic table found in their textbooks.

> So what? It was the experience that was important, repeating the process of the original scientists, not their answer. Because the process of them applying themselves to critical and creative thinking is more important than their answer (IN, C 11435).

At first this might seem to be quite at odds with his statements about the importance of an absolute reality. But what Mr. Pilgrim is talking about here is his learning objectives for his students -- that they gain an understanding of the idea of a periodic table -- rather than their coming to know a periodic table that is an absolute representation of reality. While he is concerned that the students' conception of the periodic table approach that of the periodic table as they continue to learn, he does not assume that the knowledge encoded in that periodic table would gradually approach a "perfect knowledge of that reality" as would a hypothetical realist.

The label of pragmatic constructivist also fails because Mr. Pilgrim distinguishes between the students' conception of the periodic table and one that exists separate from them. What all this suggests is that there is something fundamentally wrong with the way that constructivism is seen as epistemology when it is being used in the realm of teaching, learning, and schooling. I will return to this later.

Constructivist pedagogy

There is a set of literature that deals with constructivism as a form of pedagogy. Found here are sets of teaching techniques or models for lessons that are labeled as constructivist (Brooks, 1987; Fensham, 1989 ; Brooks and Brooks, 1993; and Leonard, Gerace, and Dufrense, 1994). In particular, in this literature, "Constructivism stands in

contrast to the more deeply rooted ways of teaching that have long typified American classrooms (Brooks and Brooks, 1993)."

Mr. Pilgrim makes this same contrast, and distinguishes constructivism from lecturing. But instead of dismissing didactic forms of teaching out of hand, he sees a purpose for different pedagogical forms. He gave as an example learning how to drive a car. In it, he contrasted learning the rules of the road with learning how to drive the car:

> What I had to learn were the rules of the road, and I learned them by written and oral lecture method -- you don't need constructivism. Rules of society are arbitrary, they must be taught by lecture method somehow (IN, C 11435).

The rules of the road, what Mr. Pilgrim would identify as knowledge in his multi-level epistemology, are best learned through a lecture method. The rules are presented to the students and they must memorize them. On the other hand, he sees actually learning how to drive the car as something that is best done through hands-on experience, and is learned in a constructivist manner.

> But my method of learning how to drive the car was my dad took me around a parking lot a few times. Then on a long drive in the desert, he threw the keys at me and said "Go for it." I drove off the side of the road ... I could drive a stick shift when I was 14. I learned how to drive with constructivism (IN, C 11435).

Mr. Pilgrim makes a similar distinction based on the educational situation (Feldman, 1994a). To illustrate this difference he compared his ninth grade physical science classes (FAST 2) with a college chemistry class:

> Now if I were to teach a course in chemistry on the college level, [I] would not want to use constructivism, because those people are paying a lot of dollar per minute and ... it's a mill. Constructivism is not efficient when it comes to use of time. It is very effective when it comes to developing someone's mind. So

> unfortunately, in college where you're supposed to develop somebody's mind, teachers are more concerned with cramming in information (IN, C 11435).

From these two examples it can be seen that Mr. Pilgrim sees constructivism and lecture as alternative forms of pedagogy. One can teach using constructivist methods or one can teach using didactic methods, or a combination of both, depending on what is being learned and the educational situation.

Constructivism as a learning theory

Constructivism is identified as a theory of learning as well as an epistemology and as a collection of pedagogical techniques (Matthews, 1992; Jakubowski, 1993; Coburn, 1993; and Reiber, 1993). In the domain of psychology, constructivism can be defined as an adherence to a theory that learners "must construct and reconstruct their own meaning for ideas about how the world works (Good, Wandersee, and St. Julien, 1993, p. 74)." In this sense, knowledge is what is learned, and people learn by constructing knowledge.

Mr. Pilgrim adheres to a constructivist theory of learning, but one that operates for only part of his multi-level epistemology:

> The lecture method of teaching is in my opinion almost without value when it comes to true learning which leads to a change of behavior of action. [But] a lecture may give you knowledge. You can go to a lecture on real estate law. You can learn a lot. But constructivism would come in when you're trying to take what you've learned and apply it to real life, experience after experience after experience. ... [I]t is actually the trying to get the knowledge out of your life experience and analyze and synthesize and apply that knowledge to your life experience (IN, C 10851).

What Mr. Pilgrim is suggesting here is that one can gain knowledge of facts, ideas, and processes that can be either true or false through didactic teaching. Constructivism then

comes into play as a way of explaining how one can learn through experience. To Mr. Pilgrim, constructivist learning also occurs when people apply what they have learned through didactic instruction. By attempting to apply what one has learned, for example, by memorization, learning can occur in a constructivist manner. In addition, he believes that constructivist learning can occur through vicarious experience, by becoming aware of the experiences of others.

Deconstructing constructivism

What I have described so far is the case of a high school science teacher who sees himself as both a constructivist and a fundamentalist. I have attempted to understand what he means by constructivism by comparing his comments to the way that experts in the field have typified constructivism in terms of epistemology, pedagogy, and psychology. But in doing so, there seems to be a significant mismatch between what we see in Mr. Pilgrim and how these authors write about constructivism. I would like to suggest that this mismatch occurs for several reasons. The first is the language of constructivism itself, and particularly its use of the word knowledge. The second is the way that constructivists separate out learning from other human activities, and identify learners primarily as school children, rather than all human beings. And the third is that little attention is paid to the complexities of teaching and learning science in schools. I look at each of these in turn, relating each to Mr. Pilgrim's perspective.

Knowledge and understanding

I begin with the use of the term knowledge. Von Glaserfeld claims that it is an illusion that there is knowledge in texts. While he admits that there is something in texts, "language -- strings of words (p. 30)," he claims that "Texts contain neither meaning nor knowledge, they are scaffolding on which readers can build their interpretation (1993, p. 30)." But the language they contain is not arbitrary. Let's take Mr. Pilgrim's example -- the periodic table. It contains strings of letters and words, symbols,

and digits. To find the periodic table useful as a source of information, one must be able to read, and be able to recognize that some of the words are the names of elements, that others identify properties, that the symbols also identify elements, and that the digits correspond to both the identity of elements and of the measure of their properties. And of course, one would need to know what is meant by element, symbol, property, and so on, to extract useful information from the periodic table. So a great deal must be put together, based on prior experiences, to find the periodic table useful. But as Mr. Pilgrim has implied, isn't the idea of the periodic table and the way that it stores information significantly different from the information itself? Once a person understands the nature of the periodic table and how to use it, it then becomes a tremendous source of ... what? Information ... ? Facts ... ? Knowledge ... ?

I use this example not to critique von Glaserfeld or other epistemological constructivists' conception of science or scientific ways of knowing, or to suggest that people do not construct meaning, or to suggest that constructivism is not a viable learning theory. Rather, what I am suggesting is that to call what we construct in our minds knowledge leads to unnecessary confusion between constructivist epistemology and constructivist psychology, and leads to the establishment of a dogma called constructivist pedagogy.

I would like to suggest that we distinguish the product of the intellectual activity of humanity from the result of learning. I have used the term knowledge to refer to the former and understanding (as a noun, not a verb) to the latter (Feldman, 1994b). Both are human constructions, but the reasons why knowledge is constructed are epistemological, while understanding is constructed due to the nature of the human mind and of human society. What I call knowledge is a collection or codification of that coming to know in ways that are what von Glaserfeld (1993) calls "viable," and I would add, acceptable to the community that has the power to decide what should count as knowledge (Foucault, 1970). What I have labeled as understanding is the situated

meaning making that results from being in situations (Heidegger, 1962; Lave and Wegner, 1991). For example, the periodic table could be referred to as knowledge while the meaning that Mr. Pilgrim's students make of it as understanding. By distinguishing in this way between knowledge and understanding I have made a distinction between epistemological and psychological constructivism. This distinction also acts against the establishment of a dogma of constructivist pedagogy. I will return to this later in the paper.

Who are the learners?

An interesting aspect of this case is that Mr. Pilgrim has chosen to apply constructivist pedagogy to adult learners. In both of the vignettes that began this paper, the inservice workshop and the Bible study classes, Mr. Pilgrim was teaching adults. This is quite different from who the students are in much of the constructivist literature. In that literature, the "learners," as the students are referred to, are school children. While that is whom we, as educators, are most concerned with, it sets up a situation in which the people who are learning are significantly different from the teachers and theorizers about teaching and learning. They are children, we are adults. But if, as it is suggested in much of this literature, that " we are all learners," and if, as Lave suggests, learning is a constitutive and ongoing aspect of being human (Lave and Wegner, 1991), then what we say about children as learners should also be true about us.[10]

This is, in a sense, what Mr. Pilgrim has attempted to do. His talk about ways of knowing reflects both the ways that he thinks of himself and other adults as learners, and the ways that he would like to help his students to learn science. By referring to his own experiences, he has distinguished between learning the rules of the road and learning how to drive. He then uses that to distinguish learning as understanding the idea of a periodic table from learning as knowing the periodic table, and can distinguish adults' constructions of their understandings of Bible stories from the knowledge that he sees in the Bible.

Because the constructivist literature focuses on school children as learners there is a tendency to conclude that since meaning making, or the construction of understanding, is an active process, learners -- school children -- learn best through engaging in hands-on activities. If the authors who make that claim were to include all human beings as learners they would see the fallacy in their logic that links learning as an active process to learning through activities. This paper is a case in point. My hope is that in reading this paper, you are learning something; that by reading these words, reflecting on them, thinking about them, and maybe through talking or writing about them, you have come to a new understanding about constructivism.

What this suggests is that if we accept constructivism as the model for human learning, then we need to see how all forms of instruction can lead to meaning making and the construction of what I call understanding for all learners, that is, all human beings.

Teaching and learning science in schools

By distinguishing between knowledge and understanding as epistemological and psychological aspects of constructivism, scientific knowledge can be recognized as a constructed human product, and what people know can be seen as a result of meaning making, or construction, in situations. By making this distinction, the pedagogical problem facing the teacher in this study and other science teachers that Driver (1983) and others have identified, disappears. The science teachers' problem -- an intellectual dishonesty -- arises from the use of techniques and language that suggests that students construct their own ideas about science, while at the same time, they are expected to arrive at the currently accepted scientific law or principle.

What this amounts to, as can be seen in Mr. Pilgrim's case, is that the teaching and learning of science in schools is significantly different from the doing of science. A school teacher finds himself or herself faced with at least three expectations re their students' learning of science. The first is that literate adults are expected to have at their

call low-level scientific concepts -- the recognition of a label for an object or event. Second, there is the expectation that adults have some understanding of higher-order concepts, such as acceleration or density, that are combinations of the low-level concepts. And adults are expected to have some understanding of the major principles and theories of science (Good, Wandersee, and St. Julien, 1993). Third, there is the expectation that science teachers instill in students some understanding of the way that science is done. Some expect more than this -- that students should be able to perform in ways that are similar to scientists.

What this appears to suggest is that the task for science teachers is to ensure that their students know, understand, and are able to do, science. However, thinking about science teaching in this way tends to dichotomize the task into the categories of content (what students are expected to know) and process (what students are expected to do), leaving understanding -- what many call "conceptual understanding" -- to hover, ghost-like, somewhere above the divide. The tendency of teachers, as with Mr. Pilgrim, is to then use didactic methods to teach content (knowledge) and constructivist pedagogy to teach scientific processes, with conceptual understanding possibly a by-product of the latter.

Again, as can be seen in these past few paragraphs, the language can be quite confusing. What is meant by knowledge, content, conceptual understanding, scientific processes, wisdom, and so on? And again, I would like to distinguish between knowledge as a product of human enterprise and understanding as the result of situated meaning making. In science education, the knowledge that is being considered consists of the low- and high-level concepts, principles, and theories of science, and the human products that we call scientific methods or processes. All of these are constructed human products. For students, as with all human beings, an understanding of science is the result of their making meaning, through a constructivist learning process, of scientific knowledge. Teaching then becomes the task of mediation, where

the teacher acts as an interface between scientific knowledge and the students (Coburn, 1993), to facilitate the students' construction of their understanding.

What, then, are the instructional methods that serve to mediate or facilitate? The answer is, "It depends." It depends upon the educational situation including who the students are, what they have experienced, what their expectations are, the knowledge considered appropriate for those students, and the educational perspectives of the teachers. A constructivist perspective can help to empower and enable teachers so that they can fashion learning activities to the circumstances in which they find themselves (Tobin and Tippins, 1993).

But the empowerment and enablement can only result if the teachers have a clear understanding of what constructivism in science education means. They need to recognize scientific knowledge as a product of human activity, and they need to accept all learning as construction of understanding through meaning making. Once this distinction is understood and accepted, teachers can choose, or invent, instructional methods that are of a wide variety of types including didactic, Socratic, and student-centered, to act as mediators and facilitators in the construction of students' understanding of scientific knowledge.

Afterword

As I think about the what I have written in the last few pages, I wonder about Mr. Pilgrim and his other "ism," fundamentalism, and how it relates to the distinction between knowledge as a human product and understanding as the result of meaning making. In my analysis of Mr. Pilgrim's constructivism, and in relating it to the varied literatures of constructivism, I did not refer at all to his fundamentalism. In some way it did not become an issue. Looking back, I see the reason for this was that Mr. Pilgrim accepts that scientific knowledge is a human construction, and, to a limited degree, accepts that learning is a construction of understanding through meaning making. But

Mr. Pilgrim believes that there is knowledge that is not a human product -- "the knowledge produced by God, some of which is found in the Bible that was produced by God, which is in this revealed knowledge and the nature of the God that produced that knowledge (Personal communication, 1994)."

Mr. Pilgrim's belief leads him to act in ways to help other people to live moral lives, to act wisely. He believes that in order to do so, "they must understand essential themes in the Bible (Personal communication, 1994)." But since he also believes that understanding arises through making meaning of knowledge -- whether it is fallible scientific knowledge or God's infallible knowledge -- he is compelled to use what he calls constructivist methods in both his science classes and his adult Bible study classes. It is in this way that Mr. Pilgrim's two "isms" are not dissonant, but harmonize for him as he attempts to "help the helpers" to do good in this world.

Notes:

[1] Although the subject of this research, Mr. Pilgrim, as he has asked to be called, would like to be referred to as an Evangelical, not as a Fundamentalist, I am using the latter term based on its religious rather than its political usage. The Oxford English Dictionary defines fundamentalism as a religious movement among US Protestants that is "based on strict adherence to certain tenets (e.g. the literal inerrancy of Scripture)... (1971, p. 399)." Mr. Pilgrim does not want to identified with those fundamentalists who "seek to create a world that fits one profile: It is patriarchal, ... anti-pluralistic, ... and it is anti-liberal (Cohen, 1993, p. B4)."

[2] In order to maintain anonymity, Mr. Pilgrim's published writings will not be referenced.

[3] Mr. Pilgrim has asked me to note that he incorporates constructivism is his science classes, and that his concept of faith, based on the teaching of Gene Scott (1994), is constructivist (Personal communication, 1994).

[4] This workshop is described in detail in a report that he wrote for the state-wide reform effort.

[5] The uncited references are to either a draft of Mr. Pilgrim's published paper (OP), or from my interviews of him (IN). In many cases, Mr. Pilgrim asked me to change his wording for this paper. I have done so.

[6] It was as part of the CA SS&C project that Mr. Pilgrim and I worked together and got to know one another.

[7] It was in this role that he developed and presented his workshop on constructivist lessons.

[8] Mr. Pilgrim and I had this conversation at MHS, which is located on the side of a mountain.

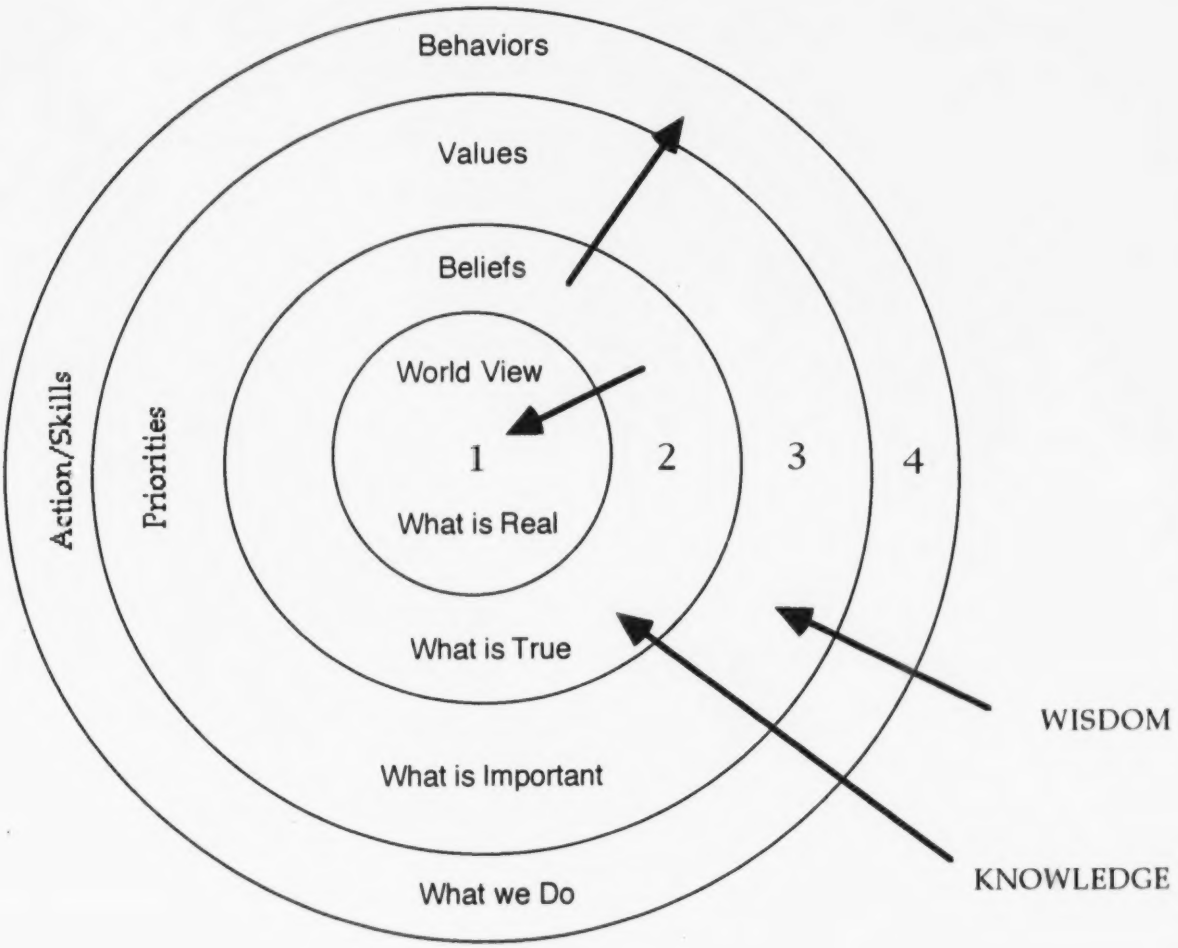
[9] This is von Glaserfeld's trivial constructivism, in which one believes that learning is built on prior knowledge.

[10] Of course there will be differences. It is important to take into account ideas about the development of the human mind, and the notion that what we learn is built upon existing cognitive structures. Even so, the image of learning that we have for children should correspond to adult learning and, to some extent, the way that we remember learning as school children. Again we must be careful here: We may not remember our own learning accurately.

Chart I:

Knowledge	Understanding	Wisdom
Facts Processes Skills	Interrelationships Gestalt	When How Why
Content of Application	Method of Application	Context of Application
Lower Intellect	Higher Intellect	Morality Ethics
Better Taught by Lecture/ Text/ Videos	Better Taught by Active Constructs	Can't be Taught by Any Method, Except Examples/ Modeling/ Life Experiences

Diagram I:


Behaviors
Values
Beliefs
World View
1
What is Real
2
What is True
3
What is Important
4
What we Do
Action/Skills
Priorities
WISDOM
KNOWLEDGE

References:

Bettencourt, A. (1993). The construction of knowledge: A radical constructivist view. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 39-49. Washington, DC: American Association for the Advancement of Science Press.

Brooks, M. (1987). Curriculum development from a constructivist perspective. Educational leadership, Dec - January, pp. 63-67.

Brooks, J. and Brooks, M. (1993). In search of understanding: The case for constructivist classrooms. Alexandria, VA: Association for Supervision and Curriculum Development.

Coburn, W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 51-69. Washington, DC: American Association for the Advancement of Science Press.

Dana, T. and Davis, N. (1993). On considering constructivism for improving mathematics and science teaching and learning. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 325-333. Washington, DC: American Association for the Advancement of Science Press.

Driver, R. (1983). The pupil as scientist? Philadelphia: Open University Press.

Feldman, A. (1994a). Erzberger's dilemma: Validity in action research and science teachers' need to know. Science education, 78(1), 83-101.

Feldman, A. (1994b). Teachers learning from teachers: Knowledge and understanding in collaborative action research. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, April 4-8, 1994. ED 369 756.

Feldman, A., Mason, C., and Goldberg, F. (1992). Action research: Reports from the field, 1991-92. San Diego: Center for Research in Mathematics and Science Education.

Feldman, A., Mason, C., and Goldberg, F. (1993). Action research: Reports from the field, 1992-93. San Diego: Center for Research in Mathematics and Science Education.

Fensham, P. (1989). Theory in practice: How to assist science teachers to teach constructively. In Philip Adey (Ed.), Adolescent development and school science, pp. 61-74. New York: The Falmer Press.

Feyerabend, P. (1975). Against method : outline of an anarchistic theory of knowledge. London : Verso

Foucault, M. (1970). The order of things: an archaeology of the human sciences. New York, Pantheon Books.

Good, R., Wandersee, J. and St. Julien, J. (1993). Cautionary notes on the appeal of the new "Ism": Constructivism in science education. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 71-87. Washington, DC: American Association for the Advancement of Science Press.

Goodson, I. (1991). Sponsoring the teacher's voice: Teachers' lives and teacher development. Cambridge journal of education, 21(2), 35-45.

Heidegger, M. (1962). Being and time. San Francisco: Harper San Francisco.

Jakubowski, E. (1993). Constructing potential learning opportunities in middle grades mathematics. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 135-144. Washington, DC: American Association for the Advancement of Science Press.

Kuhn, T. (1970). The structure of scientific revolutions. Chicago : University of Chicago Press.

Lakatos, I. (1978). The methodology of scientific research programmes. New York: Cambridge University Press.

Lave, J. and Wegner, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Leonard, W., Gerace, W. and Dufrense, R. (1994). A constructivist lesson outline. Xerox.

Matthews, M. (1992). Constructivism and the empiricist legacy. In M. Pearsall (Ed.),Scope, sequence, and coordination of secondary school science, volume II: Relevant research, pp. 183-196. Washington, DC: National Science Teachers Association.

Miles, M. and Huberman, M. (1984). Qualitative data analysis: A sourcebook for new methods. Newbury Park, CA: Sage Publications.

Noddings, N. (1990). Constructivism in mathematics education. In R. B. Davis, C.A. Maher, and N. Noddings (Eds.), Constructivist views on the teaching and learning of mathematics. Reston, VA: National Council of Teachers of Mathematics.

NRC (1994). National Science Standards, Draft November 1994. Washington, DC: National Academy Press.

Rieber, L. (1993). A pragmatic view of instructional technology. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 193-212. Washington, DC: American Association for the Advancement of Science Press.

Tobin, K. and Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 3-22. Washington, DC: American Association for the Advancement of Science Press.

von Glaserfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (Ed.), The practice of constructivism in science education, pp. 23-38. Washington, DC: American Association for the Advancement of Science Press.

Yin, R. (1989). Case study research: Design and methods. Newbury Park, CA: Sage publications.